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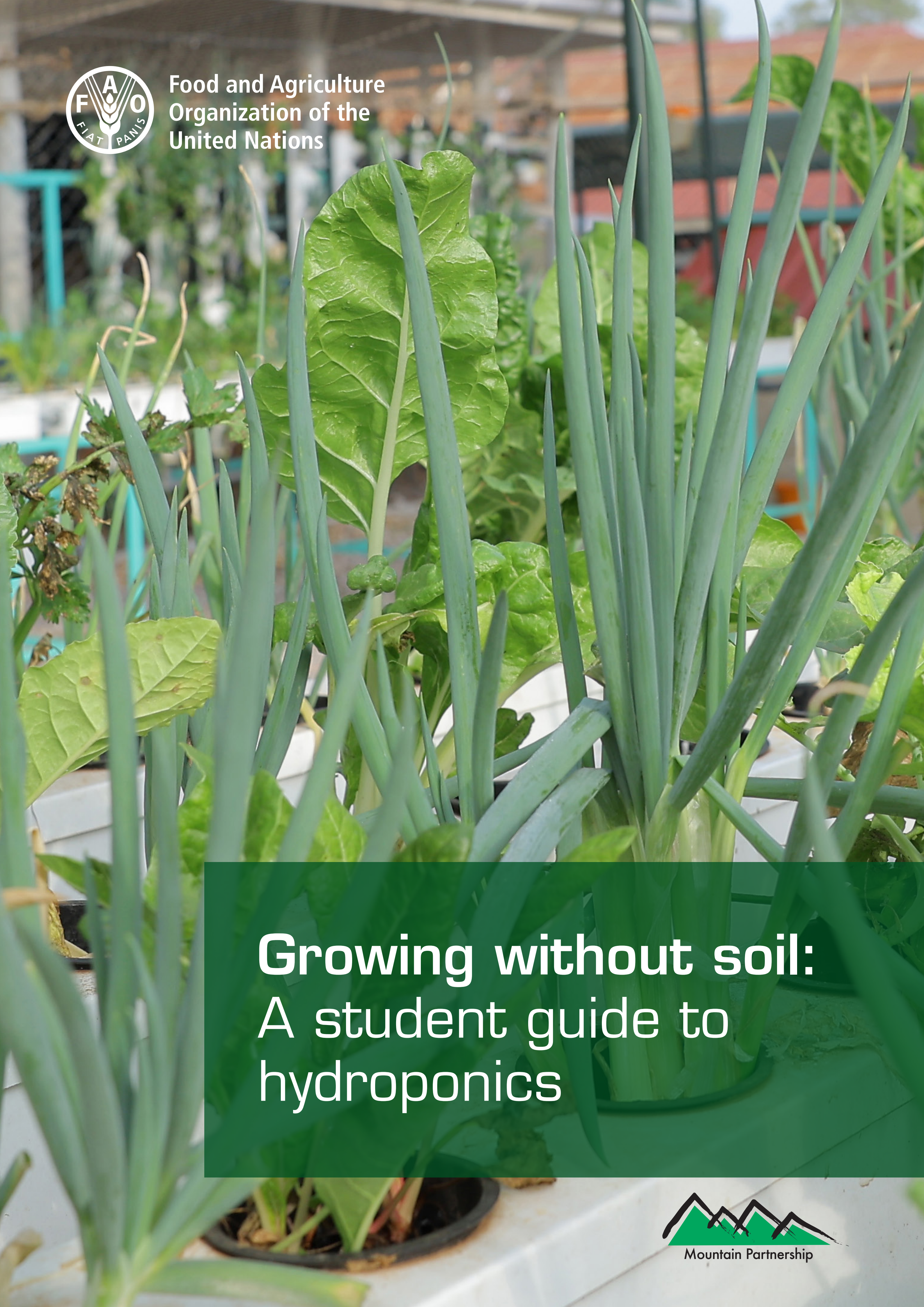

Growing without soil: A student guide to hydroponics

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Growing without soil:
A student guide to hydroponics

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H4O Hydroponic Organic Cultivation

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Cover and back photographs: Spinach grows in bounty in the hydroponic system © John Kiwagalo

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Abbreviations

DO	dissolved oxygen
DWC	deep water culture
EC	electrical conductivity
ECA	expanded clay pellets
K	potassium
LED	light-emitting diode
N	nitrogen
NFT	nutrient film technique
NPK	nitrogen, phosphorus, potassium
P	phosphorus
PE	polyethylene
pH	potential of hydrogen (measure of acidity/alkalinity)
PN	pressure nominal
PP	polypropylene
PPM	parts per million
PVC	polyvinyl chloride
RO	reverse osmosis

Glossary of technical terms

This glossary provides definitions of technical terms used in the manual for quick and easy reference.

aeration: The process of adding oxygen to water; essential for plant roots and fish in aquaponics.

aeroponics: A type of hydroponics where plant roots hang in the air and are sprayed with a fine mist of nutrient solution.

air stones: Small, porous devices connected to an air pump that release streams of tiny bubbles into water. By breaking air into many small bubbles, they increase the amount of oxygen dissolved in the water. This oxygenation is vital for healthy plant roots in hydroponics and for fish and bacteria in aquaponic systems.

ammonia: A compound released by fish waste in aquaponics; toxic to plants and fish if not converted by bacteria.

aquaponics: A system combining fish farming (aquaculture) with hydroponics, where fish waste provides nutrients for plants.

biofilter: A filter containing special materials that provide surface area for bacteria to grow, which convert fish waste into plant nutrients.

biological filtration: The natural process where bacteria convert harmful substances like ammonia into nitrates that plants can use.

compost tea: A liquid fertilizer made by soaking compost in water; used in organic hydroponics as a natural nutrient source.

coco coir: A growing medium made from coconut husks; used instead of soil to support plant roots.

deep water culture (DWC): A hydroponic system where plant roots float directly in a nutrient-rich, oxygenated water tank.

diffuser: A device connected to an air pump that releases air bubbles into water, increasing oxygen levels.

dynamic pressure: The water pressure in motion, influenced by flow speed and friction inside pipes.

Dutch buckets (Bato buckets): A Dutch bucket hydroponic system is a type of container that uses inert growing media and nutrient reservoirs to grow plants in buckets or pots without soil.

electrical conductivity (EC): A measurement of how many dissolved salts (nutrients) are in the water which tells growers if the nutrient solution is strong enough.

ebb and flow (Flood and drain): A system that temporarily floods a grow tray with nutrient solution and then drains it back into a reservoir. This cycle repeats regularly, ensuring that roots receive both nutrients and water during the flood and fresh oxygen during the drain phase.

expanded clay pellets (ECA): Small, round clay balls used as a durable, reusable growing medium that also provides surface for bacteria.

filtration: The process of cleaning water by removing particles or unwanted substances.

flow rate: The amount of water a pump moves per minute.

head pressure (Head lift): The maximum height a pump can push water upward; important when designing vertical systems.

hydroponics: A method of growing plants without soil, using water with dissolved nutrients.

inert growing medium: A material (like perlite or rockwool) that supports plant roots but does not add nutrients.

lapillo (volcanic rock): A porous material that provides good space for bacteria in biofilters but breaks down over time.

macronutrients: Nutrients plants need in large amounts: nitrogen (N), phosphorus (P), potassium (K).

micronutrients: Nutrients plants need in very small amounts: Iron, Zinc, Copper, Manganese, Boron, etc.

net pots: Small mesh-like containers that hold plants in hydroponic systems while letting water and nutrients flow through.

nitrate: A safe form of nitrogen that plants can use, produced by bacteria converting nitrite in aquaponics.

nitrite: A compound formed when bacteria break down ammonia.

nitrification: The process through which bacteria convert ammonia to nitrite and then to nitrate, making fish waste usable for plants.

nutrient film technique (NFT): A hydroponic method where a thin film of nutrient-rich water flows through slanted channels, feeding plant roots.

organic hydroponics: Hydroponics that uses natural fertilizers (like compost tea or fish extract) instead of synthetic chemicals.

o-ring: A rubber seal in pipe connections that prevents leaks without using glue.

osmosis: The natural movement of water across a semi-permeable membrane (like plant root cells), from an area with fewer dissolved substances (low salt concentration) to one with more (high salt concentration).

reverse osmosis (RO): A water purification process where pressure is applied to force water through a semi-permeable membrane, filtering out salts, minerals and impurities. In hydroponics, reverse osmosis units are often used to produce pure water before adding nutrients.

perlite: A white, lightweight volcanic rock used as a growing medium.

pH: A scale measuring how acidic or basic a solution is; plants usually grow best between 5.5 and 6.5 in hydroponics.

polyethylene (PE) pipes: Flexible, durable plastic pipes commonly used in hydroponic systems for water transport.

polypropylene (PP) pipes: Rigid, chemical-resistant pipes often used for drainage in hydroponic systems.

polyvinyl chloride (PVC): A common plastic not recommended for food-growing systems because it can release harmful chemicals.

pressure nominal (PN) rating: A number showing how much pressure a pipe can safely handle (e.g., PN6 = 6 bars).

recirculation: When water and nutrients are reused in a system instead of being wasted.

rockwool: A fibrous growing medium made from melted rock and used to start seedlings.

static pressure: The pressure of water at rest due to gravity, based on the height of the water column.

submersible pump: A pump placed inside water, cooled by the liquid around it; often used in smaller systems.

vertical tower system: A hydroponic setup where plants grow in tall, stacked towers, saving space and maximizing production in small areas.

wick system: A simple hydroponic method where a cotton rope (“wick”) pulls water and nutrients up to the plant roots from a reservoir.

Curriculum objectives

This handbook on hydroponics is designed to provide students with both theoretical knowledge and practical skills in soilless cultivation systems. Its objectives are to:

- Introduce the principles of hydroponics and aquaponics, including their advantages, limitations and sustainability potential compared to traditional soil-based agriculture.
- Familiarize learners with the main hydroponic cultivation techniques (NFT, Dutch buckets, vertical towers, among others) and guide them in selecting appropriate systems for different crops and spaces.
- Develop technical competences in system planning, hydraulic design, pump and piping selection and biological filtration management.
- Equip students with the ability to operate, monitor and maintain hydroponic installations through routine checks, nutrient management and troubleshooting.
- Explore the role of hydroponics and organic hydroponics in shaping plant nutrition, food safety and the production of high-quality, pesticide-free crops.

By completing this curriculum, students will be able to design, build and manage small-to-medium-scale hydroponic systems, while understanding their practical applications in sustainable agriculture, urban farming and food security.

Students collecting a fresh harvest

© Helen Lugada

Seedlings in the hydroponic system

© Kaytics

Introduction

What is hydroponics and how does it work

Hydroponics is a method of cultivating plants without soil, where roots grow in nutrient-rich water solutions or inert growing media such as perlite, rockwool or coco coir. Instead of extracting minerals from soil, plants directly absorb essential nutrients dissolved in water, improving efficiency and control over their growth. As the root system is continuously supplied with oxygen, water and precise nutrient balances, plants often grow faster and more uniformly than in conventional soil farming. Hydroponics can be implemented in both small-scale hobby systems and large-scale commercial greenhouses, making it a versatile approach to modern agriculture.

General advantages and disadvantages of using hydroponics and aquaponics compared to soil-based agriculture

- No soil is involved, so there is no risk of soil pollution, salinization or contamination.
- Soil-borne pathogens, fungi and weeds are largely avoided, reducing the need for pesticides and herbicides.
- Aquaponics uses nutrient-rich water from fish tanks to fertilize plants, creating a closed-loop system that supports sustainability and resource efficiency.
- Faster crop cycles, earlier harvests and sometimes higher yields due to optimized nutrient availability.
- Space and water-efficient, as plants can be stacked vertically while using up to 90 percent less water than conventional farming.

Challenges include:

- Higher initial investment in infrastructure (pumps, lights, sensors).
- Need for careful monitoring of nutrients, pH and water quality.
- Vulnerability to system failures, which can quickly stress or kill plants.

Different techniques of cultivation

There are several types of hydroponic systems, each suited to different crops and conditions. The following section outlines the main options and their key characteristics.

Among the many hydroponic methods available, three notable systems are nutrient film technique, Dutch buckets and vertical tower systems, which stand out for their versatility and wide use in commercial and small-scale setups.

Nutrient film technique

Nutrient film technique (NFT) is one of the most common hydroponic systems for leafy greens and herbs. A thin film of nutrient-rich water flows through sloped channels where plant roots rest, providing constant access to water, nutrients and oxygen. The shallow layer improves oxygenation, supporting rapid growth and healthy roots. NFT is space-efficient and works well for lightweight crops such as lettuce, spinach, basil and other small herbs. However, it is sensitive to interruptions: pump failures or blockages in channels can quickly dry out roots and damage crops.

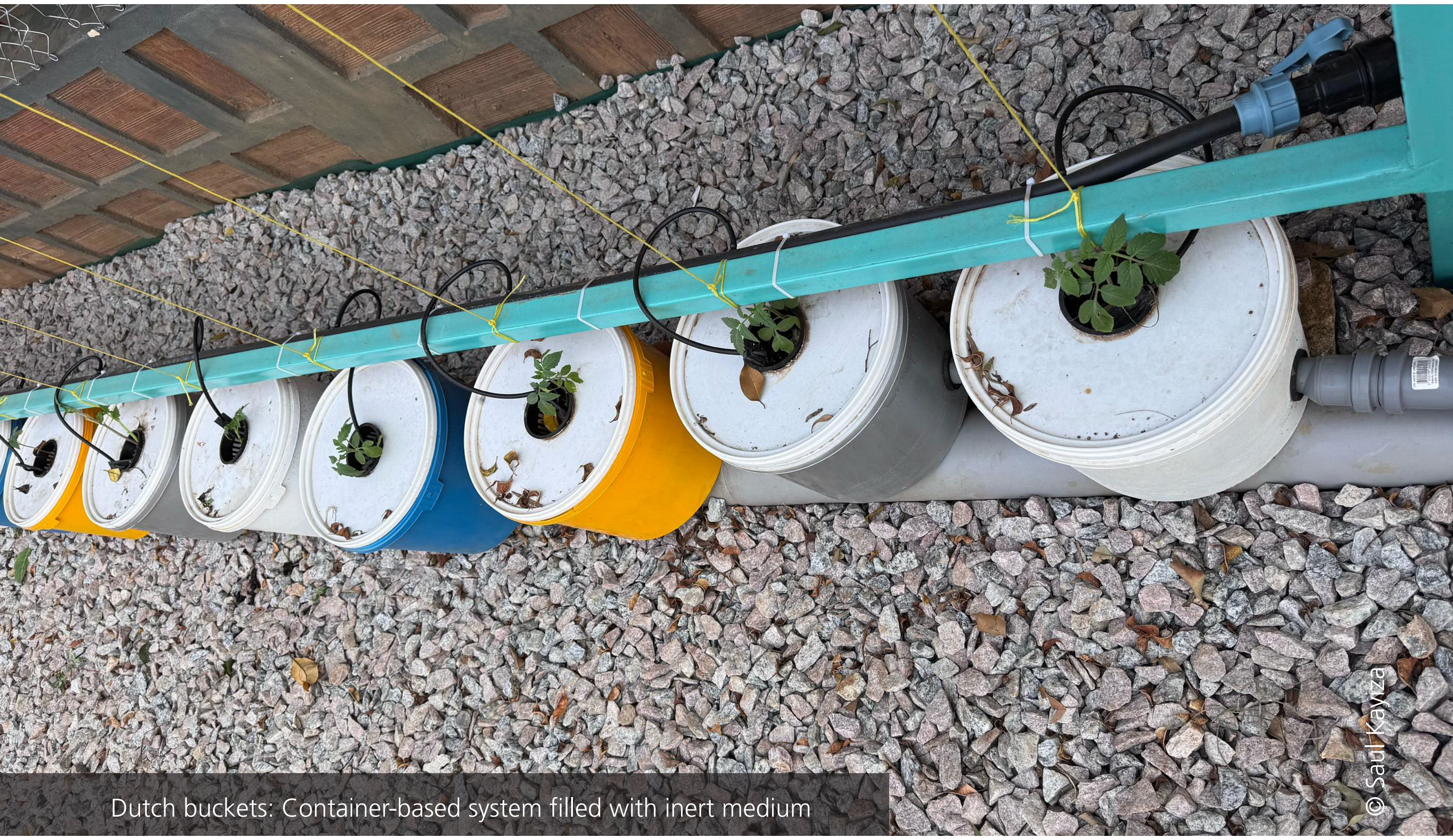
Dutch bucket system

Dutch buckets (also known as Bato buckets) are container-based hydroponic systems mainly used for larger, fruiting crops such as tomatoes, cucumbers, peppers and even vine crops like melons. Each bucket is filled with an inert growing medium (commonly perlite, expanded clay or coco coir) that supports the plant's root system. A drip irrigation line supplies the nutrient solution to each bucket, which then drains into a central reservoir for recirculation or disposal. The advantage of this system lies in its scalability and flexibility as buckets can accommodate large, heavy plants, making it ideal for greenhouse production. It also provides growers with a high level of control over irrigation and fertilization, while remaining relatively simple and robust compared to NFT.

Tower systems

Vertical tower systems maximize production by stacking plant sites vertically in towers or columns. Nutrient solution is pumped to the top of the structure, trickling down through the root zones before being collected and recirculated. This setup is especially valuable in urban farming, as it allows for high-density cultivation of leafy greens, strawberries and herbs. Key advantages are space efficiency, lower land requirements and visually appealing structures that can also serve educational or consumer-facing purposes. The main challenge is ensuring uniform water distribution, as plants at the bottom may receive less oxygen or nutrients.

Other hydroponic methods are also widely used. Deep water culture (DWC) suspends plant roots directly in an aerated nutrient solution, ensuring constant access to water and oxygen. Ebb and flow (Flood and drain) systems periodically flood a grow tray before draining it back, balancing hydration and aeration. Drip systems, often used for fruiting crops such as tomatoes and peppers, deliver nutrients directly to the plant base and can operate as recirculating or run-to-waste setups. Aeroponics exposes roots to air and applies nutrients as a fine mist, maximizing oxygen but requiring precise management. Simple passive approaches, like the Kratky method or wick systems, offer low-cost, low-maintenance options suitable for small-scale or beginner use.


Dutch buckets: Container-based system filled with inert medium

© Saul Kayiza

80cm
INGCO
INDUSTRIAL
80cm

Students assembling the hydroponic structure

© Helen Lugada

1

Planning a hydroponic system

Hydroponic Organic 4.0

A diverse range of plants growing in the hydroponic system

© John Kiwagalo

Designing a hydroponic or aquaponic installation is not just a matter of assembling pumps and pipes; it requires system-level thinking[1]. Each element of the design, from plant layout to water circulation, interacts with the others and determines the overall efficiency, sustainability and productivity of the system. Careful planning minimizes technical failures, reduces operational costs and ensures that crops grow under stable and optimized conditions.

A well-planned hydroponic system considers:

- **Plant organization**: categorizing species by size and growth cycle to match them with the most suitable cultivation technique.
- **Space orientation**: arranging the layout to maximize exposure to natural or artificial light while ensuring accessibility for maintenance.
- **Hydraulic design**: ensuring consistent water flow, correct pump sizing and adequate aeration for healthy root development.
- **Pumping and piping systems**: selecting materials, diametres and fittings that guarantee durability and food safety.
- **Filtration and water quality management**: maintaining nutrient balance and, in aquaponics, transforming fish waste into plant-available resources through biological processes.

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[1] System-level thinking refers to a way of learning your way to effective action by looking at connected wholes rather than separate parts. For more information: *https://www.praxisframework.org/en/library/systems-thinking*

In practice, this means thinking ahead not only about what to grow, but also where and how to grow it, considering both the immediate technical needs and the long-term sustainability of the installation. The following sections break down the planning process into logical steps, moving from plant selection to hydraulic engineering, so that the system can function efficiently as a whole.

Plant zoning and system matching

Deciding the type of plants to grow is the starting point for selecting a cultivation system. In other words, the crop comes first and the system follows. This choice then influences other key aspects of design, such as how to arrange the space (spatial considerations), how water will circulate and what kind of pumps will be needed.

Plants should be divided into macro-categories based on their size and growth cycle:

- **Large plants, long cycle** (e.g. tomatoes, cucumbers, peppers) → best suited for Dutch buckets.
- **Small plants, short cycle** (e.g. lettuce, basil, leafy greens) → ideally grown with NFT channels.
- **Medium-sized plants, medium cycle** (e.g. strawberries, herbs, compact greens) → can be cultivated in vertical towers to save space.

Table 1. Matching plant categories with suitable hydroponic systems and key advantages

Plant category	Typical crops	Best system	Key advantages
Large plants, long cycle	Tomatoes, cucumbers, peppers, melons	Dutch buckets	Supports large root systems, scalable, robust for fruiting crops
Small plants, short cycle	Lettuce, basil, leafy greens	NFT	Efficient for lightweight crops, fast growth, space-saving
Medium plants, medium cycle	Strawberries, herbs, compact greens	Vertical towers	Maximizes vertical space, ideal for urban/ indoor setups

Applying final touches to the supporting structure

© Helen Lugada

Spatial considerations and orientation

To maximize plant growth and system efficiency, the orientation of rows or channels should be considered during installation. For systems such as NFT lines, a general guideline is to align them east–west.

Why east–west?

This orientation helps to optimize sunlight exposure and minimize shading. As the sun moves from east to west, both sides of the row receive more uniform light. A north–south orientation can leave one side exposed and the other shaded, especially at midday.

Uniform light distribution supports more consistent and balanced growth across the entire cultivation area, leading to higher system efficiency.

Maximizing growth efficiency

The goal of this spatial strategy is to maximize the growth efficiency of the system. Uniform light distribution allows all plants to photosynthesize effectively, leading to:

- **Higher yields:** Even light exposure supports healthy development for every plant, reducing the number of stunted or less productive ones.
- **Reduced resource waste:** By promoting consistent growth, the system’s resources (water, nutrients) are used more efficiently.

- **Improved crop quality:** Uniform growth leads to more consistent product size, shape and quality.

In essence, an east–west orientation is a straightforward design choice that leverages natural light patterns to create a more productive and balanced growing environment for the plants.

Hydraulics and water circulation

Hydraulics and water circulation are central to the performance of any hydroponic or aquaponic system. Proper water movement ensures that nutrients and oxygen reach plant roots efficiently, while pumps and plumbing maintain the flow needed for healthy growth. Understanding key concepts such as flow rate, head pressure and water pressure is essential for designing a system that delivers water reliably to all parts of the cultivation setup.

Flow rate and head pressure

- **Flow rate**: The flow rate is the volume of water the pump moves per unit of time (e.g. litres per minute). It must be tailored to the specific plants and system design. If the flow is too slow, roots may suffer from nutrient deficiencies and low oxygen levels. If the flow is too fast, roots can be physically stressed and nutrients absorbed less efficiently.
- **Head pressure (head lift)**: Head pressure or head lift, is the maximum vertical height a pump can push water. This is a critical factor in pump selection, as the head pressure increases, the pump's actual flow rate decreases.
- Selecting a pump with a head rating higher than the system's maximum lift, while accounting for friction losses in pipes, ensures the pump can deliver the required flow rate throughout the system.

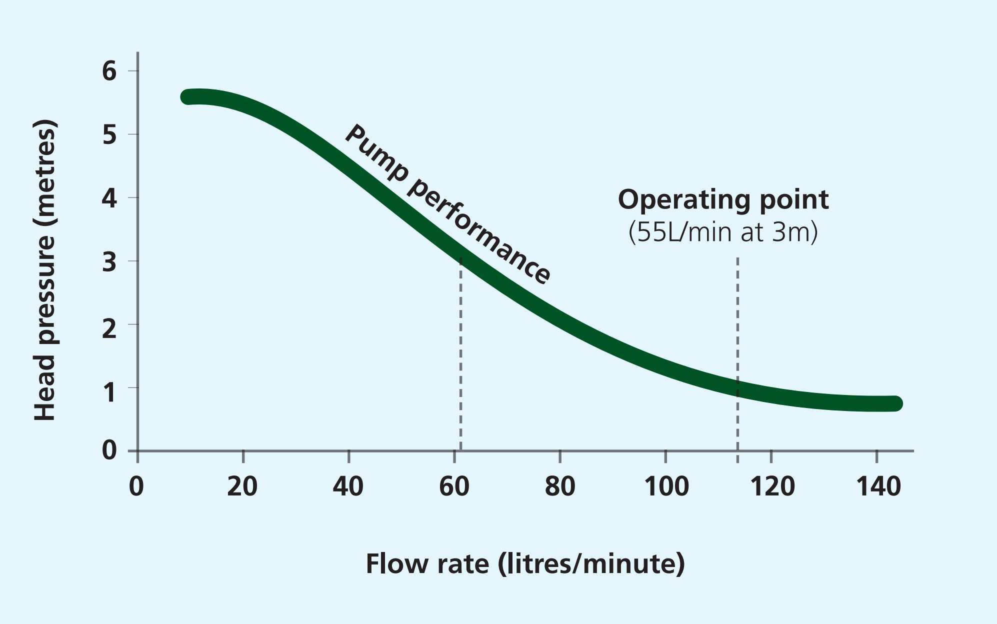
Pressure

Water pressure is measured in bar (1 bar ≈ a 10 m column of water).

- **Static pressure** is the pressure of water at rest, as a result of gravity. For a vertical system, it is determined by the height of the water column.
- **Dynamic pressure** is the pressure of moving water. This pressure is influenced by the velocity of the water and energy losses due to friction as the water moves through pipes, bends and fittings.

When sizing a pump, both pressures must be considered. The total dynamic head requirement of your system is the sum of the vertical lift (static pressure) and the frictional losses throughout the plumbing (dynamic pressure). Selecting a pump that can overcome this total dynamic head is key to ensuring consistent and effective water circulation.

Figure 1. Pump performance curve showing the relationship between flow rate and head pressure



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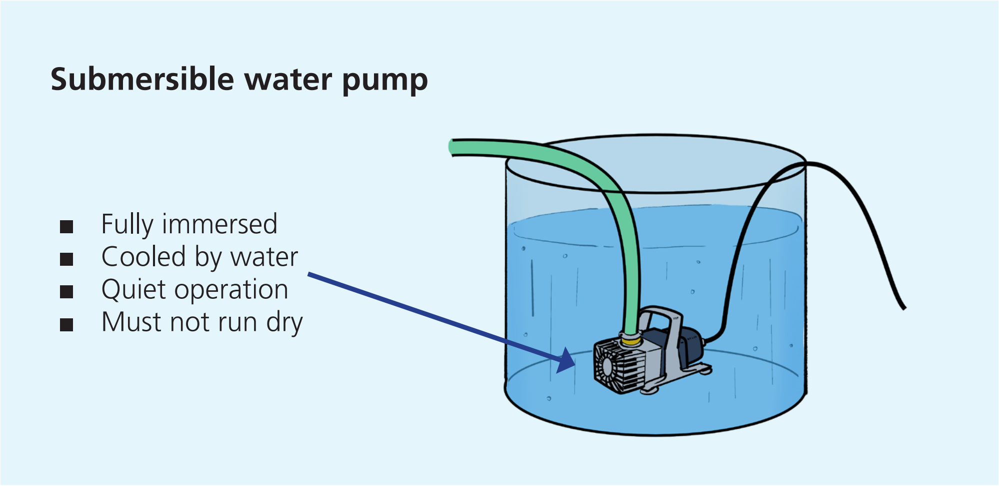
Pump selection

Choosing the right pump is critical for maintaining consistent water flow and system performance. The type, capacity and placement of a pump determine how efficiently nutrients and oxygen are delivered to plant roots.

Water pumps

Submersible pumps: These are designed to be fully immersed in water. The surrounding liquid keeps the engine cool, preventing it from overheating. They are also generally quiet and self-priming, making them simple to install and operate. It is important to ensure they never run dry, as this can cause the engine to burn out. Submersible pumps are categorized as either clear water (for clean, debris-free water) or dirty water (for larger impellers designed to handle solid particles and waste without clogging).

Figure 2. Submersible water pump used in hydroponic systems


Submersible water pump
■ Fully immersed
■ Cooled by water
■ Quiet operation
■ Must not run dry

© Peter Mugeni

External pumps: also known as in-line pumps, external pumps are installed outside of the water reservoir. They are typically more powerful and suitable for larger systems. A major benefit of external pumps is the ease of maintenance and repair, as they can be serviced without being removed from the water. They are also not susceptible to the thermal limits of the surrounding water. Unlike submersible pumps, they must never be submerged.

Regardless of the type, every pump has a performance curve that illustrates its flow rate (volume of water) at different head pressures (vertical lift). For maximum efficiency and longevity, choose a pump whose typical operating point falls near the centre of this curve. This avoids overworking the pump at the extremes of its capacity.

Figure 3. External (in-line) water pump for hydroponic installations

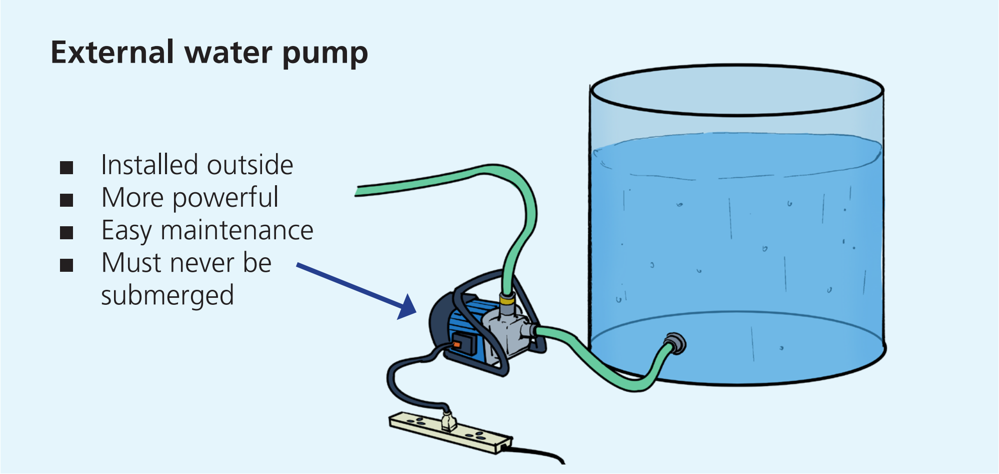

External water pump
■ Installed outside
■ More powerful
■ Easy maintenance
■ Must never be submerged

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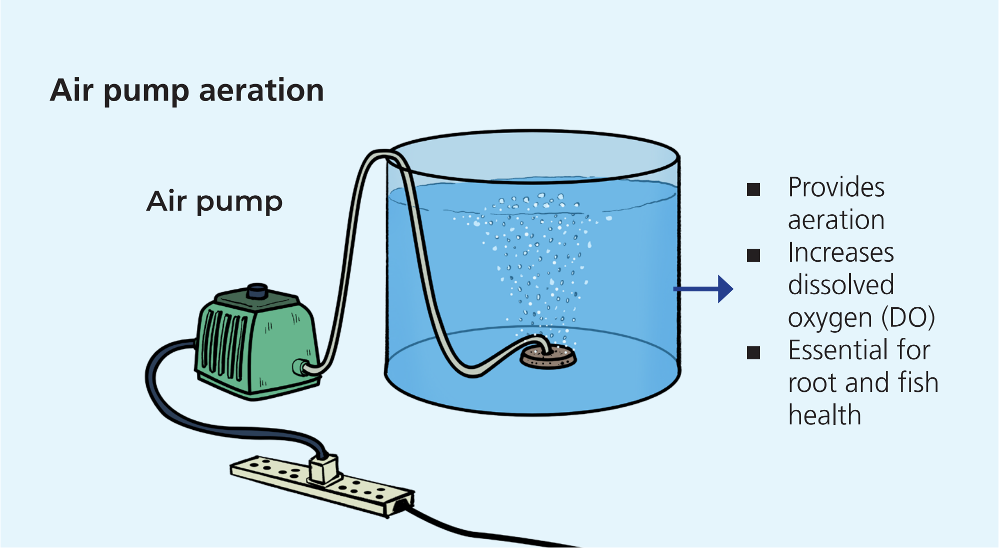
Figure 4. Air pump providing aeration and dissolved oxygen in a hydroponic system


Air pump aeration
Air pump
■ Provides aeration
■ Increases dissolved oxygen (DO)
■ Essential for root and fish health

© Peter Mugeni

Air pumps

Air pumps are essential for aeration, which is the process of introducing oxygen into water. This is a critical factor for dissolved oxygen (DO) levels. Plant roots require oxygen for nutrient and water absorption. In aquaponics systems, adequate DO is also vital for the health of fish and beneficial bacteria. Air pumps are selected based on their flow rate (in litres per minute or L/min) and pressure, which must be sufficient to overcome the depth of the water column and push air through the diffusers.

Secondary pumps

In addition to the main circulation pump, more complex systems may use secondary pumps to handle specific tasks. These can include booster pumps to increase water pressure for a specific section of the system or circulation pumps used to maintain a homogenous nutrient solution within a large reservoir, preventing nutrients from settling. While not the primary pumps for the system’s main flow, auxiliary pumps can be crucial for maintaining system stability, ensuring uniform nutrient distribution and improving overall reliability.

Piping and connections

Pipes, fittings and system layout are essential for moving water safely and efficiently in hydroponic and aquaponic systems. Choosing the right materials, planning the placement of tanks and channels and using appropriate connectors ensures reliable nutrient delivery, prevents leaks and reduces maintenance challenges.

Pipe materials

There are different types of pipes to choose from, each suited to specific parts of a hydroponic or aquaponic system. The selection depends on factors such as water type, pressure requirements, chemical resistance and durability, helping to ensure safe and efficient nutrient circulation.

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Polyethylene (PE): This is the preferred material for water supply lines due to its flexibility, durability and chemical inertness. It is resistant to UV radiation and does not leach harmful compounds into the water, making it a safe choice for circulating nutrient solutions. PE pipes are classified by their pressure nominal (PN) rating, which indicates a pipe's maximum working pressure in bars. A PN6 pipe can withstand up to 6 bars of pressure, while a PN10 pipe can handle 10 bars. Greater wall thickness results in a higher PN rating, increasing its resistance to pressure.

© Arianna Bartolozzi

Polypropylene (PP): This material is commonly used for drainage pipes due to its rigidity and chemical resistance, making it suitable for nutrient-rich return water. Connections should use fittings with O-rings rather than adhesives. O-rings create a durable, leak-free, mechanical seal that is easily disassembled for maintenance. This also prevents the risk of adhesives or solvents leaching into the system and contaminating the water.

Polyvinyl chloride (PVC): This material is not recommended for water-based cultivation systems. It can contain plasticizers and other additives that can leach into the water over time. Compounds, such as vinyl chloride, are toxic and can be harmful to both plants and humans, making PVC unsuitable for food production systems.

System layout

The placement of system components should make use of gravity to improve efficiency. The most effective design positions the main water storage tank below the cultivation systems, allowing water to return naturally by gravity. This also reduces the energy required for circulation. The main pump then only needs to lift water to the highest point, from where it flows down through the channels.

If the main storage tank cannot be placed at the lowest point, a relay tank and a secondary pump may be used. In this setup, a small pump moves water from the main reservoir to the relay tank and a primary pump distributes it to the system. This design is less energy-efficient but is sometimes necessary to accommodate space constraints or specific layouts.

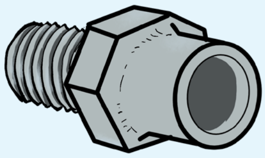
Fittings and accessories

While it is easy to focus on the big components of a system, such as pumps and pipes, the small parts are what holds everything together. Fittings and accessories are crucial for creating a leak-proof, durable and adaptable system.

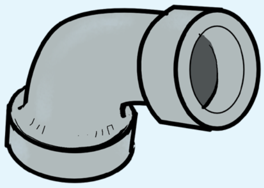
Types of fittings and their functions

Fittings are the connectors that join pipes and equipment. They come in many forms, each with a specific purpose.

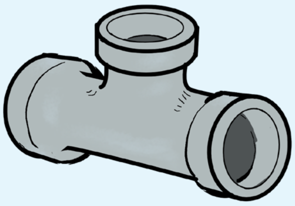
Figure 5. Common pipe fittings used in hydroponic systems and their functions



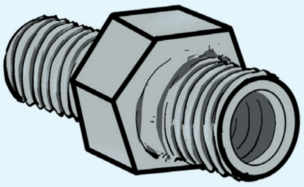
Adapter
Used to join pipes or components with different types of connections



Elbow
Fittings with a bend that changes the direction of the pipe run



Tees
Used to split the flow of water, allowing you to create multiple branches from a single supply line



Nipples
Short, male-threaded pipe sections used to connect two female-threaded fittings

© Peter Mugeni

The inches vs. millimetres challenge

A common challenge in system building is the difference between pipe and fitting sizes. Pipes, particularly those made of polyethylene (PE) or polypropylene (PP), are typically specified in millimetres (mm), referring to their outside diametre. However, threaded fittings on pumps or tanks are often measured in inches and are based on a historical imperial pipe size—which is not the actual diametre, but an approximate inside diametre.

This means you can't simply match a 25mm pipe to a 1-inch fitting and expect a perfect fit. The actual outside diametre of a pipe and the imperial size of a threaded fitting rarely match up. For example, a common PE pipe might have an outside diametre of 20mm, which corresponds roughly to a ½-inch threaded fitting. Always verify the actual dimensions and use the appropriate adapter to ensure a secure, leak-free connection.

Biological filtration (aquaponics focus)

In aquaponics, fish produce waste that releases ammonia, which is harmful to both fish and plants if it builds up. Biological filtration is the process where special bacteria naturally break this waste down into safer compounds that plants can use as nutrients. Without this process, ammonia would reach toxic levels, kill fish and collapse the system.

Biofilter types and materials

Biofilters work by providing surface area where these helpful bacteria can live. The bigger the surface area, the more bacteria can grow and the more efficiently waste can be converted. Different materials are used for biofilters and each has its strengths:

- **Expanded clay pellets (ECA):** Light, durable and pH-neutral. They do not break down and are great for growing beds where the media serves as the biofilter.
- **Volcanic rock (lapillo):** Very porous, so bacteria grow well on it. However, it can break down over time, making it less durable.
- **Engineered media (bioballs, biocrystals):** Specially designed to pack lots of surface area into a small space. Best for separate biofilter units where space is limited.
- **Pressurized filters:** Use pumps to push water through the growing media, ensuring it contacts as much surface as possible. This increases efficiency and speeds up the breakdown process.

The nitrification process

The main role of the biofilter is to run the nitrification process, which happens in two steps:

1. Ammonia → nitrite

- Fish release ammonia into the water.
- Bacteria called *Nitrosomonas* convert ammonia into nitrite.
- Nitrite is still harmful to fish, so the process must continue.

2. Nitrite → nitrate

- Other bacteria, *Nitrobacter*, convert nitrite into nitrate.
- Nitrate is much safer and is the main form of nitrogen that plants can absorb and use to grow.

Figure 6. Nitrification process in aquaponic systems

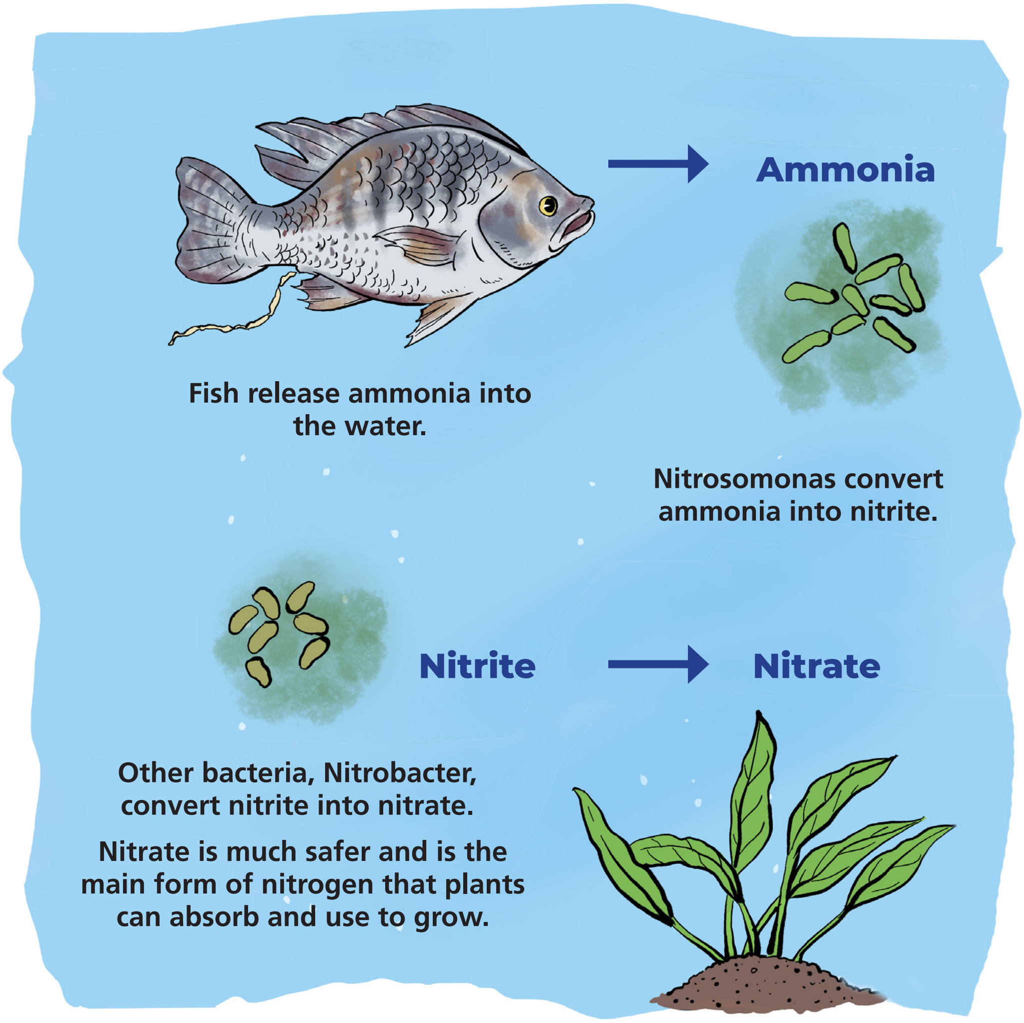

Ammonia
Fish release ammonia into the water.
Nitrosomonas convert ammonia into nitrite.
Nitrite
Nitrate
Other bacteria, Nitrobacter, convert nitrite into nitrate.
Nitrate is much safer and is the main form of nitrogen that plants can absorb and use to grow.

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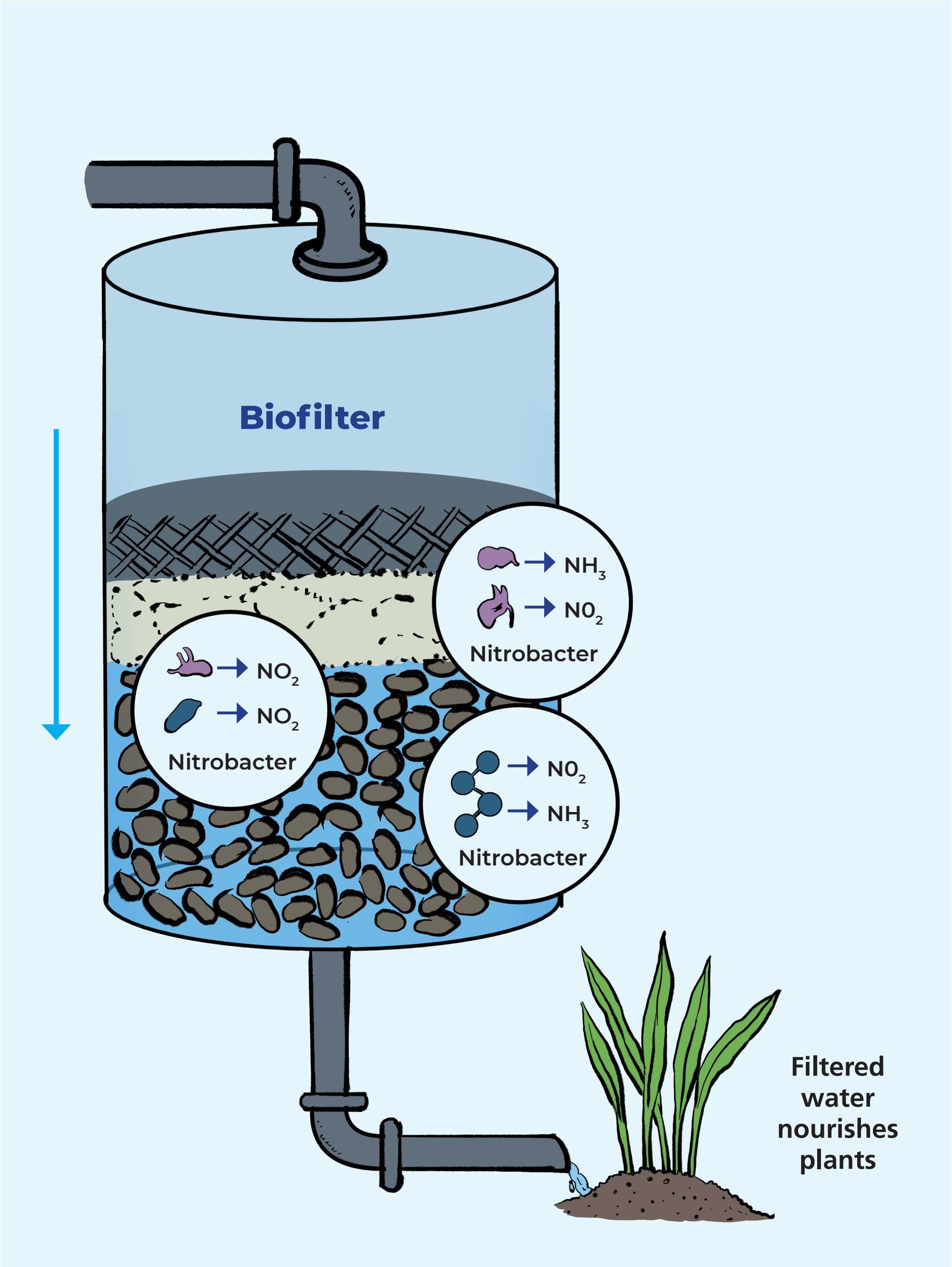
Figure 7. Nitrification process in aquaponic systems


Biofilter
→ NH3
→ NO2
Nitrobacter
→ NO2
→ NO2
Nitrobacter
→ NO2
→ NH3
Nitrobacter
Filtered water nourishes plants

© Peter Mugeni

Using pots and seedlings with soil clods

When starting hydroponic cultivation with seedlings that still have a small clod of soil around their roots, it is important to handle them correctly so that they adapt smoothly to the new growing environment.

Avoid washing the roots: rinsing off the soil may seem like a good idea, but it actually stresses the plant, slows down recovery and delays root development in water. Instead, wrap the soil clod in organic cotton gauze. This prevents soil from dispersing into the water but allows the roots to breathe. If the plant needs to be replaced, this gauze is biodegradable and can be disposed of with organic waste.

Use net pots: these are mesh-like containers, usually made of plastic that are designed specifically for hydroponics. They hold the seedling firmly while letting water and nutrients flow freely to the roots. Net pots come in different sizes and it is important to select one that matches the plant type and the system in use. The planting hole (the opening where the plant is placed) in the hydroponic channel or vertical tower should not be too small, otherwise plant growth could be restricted.

By combining gauze wrapping with the correct net pot size, seedlings with soil clods can establish themselves more easily in water systems than if placed directly into the system, supporting healthy growth and keeping the setup clean.

Plants in net pots ready to be placed in the system

© Helen Lugada

Maintenance of water pumps

© Helen Lugada

2 Maintenance

Proper maintenance ensures that plants receive the right amount of water, oxygen and nutrients, while also preventing technical malfunctions that could compromise an entire crop. Maintenance can be divided into frequent check-ins (daily/weekly tasks) and long-term maintenance (monthly/seasonal tasks).

Frequent check-ins

Keep the nutrient solution flowing smoothly

Plants rely on the nutrient solution that circulates through the system. If the nutrient solution does not flow evenly, some plants may receive too much or too little.

Vertical towers and Dutch buckets: check that the small capillary tubes are not blocked, otherwise certain plants might be left "thirsty".

Nutrient film technique (NFT) channels: ensure that the solution level is consistent along the entire channel. If it is too low, roots can dry out; if it is too high, roots may lack oxygen.

Monitoring the system (EC and other parameters)

Monitoring can be done easily through the application connected to the system. The most important value to track is electrical conductivity (EC), which tells you how many dissolved salts are in the solution. Via the app, you can also monitor water temperature and other key parameters to ensure the system stays balanced. Additionally, the system can be controlled remotely via Wi-Fi, providing flexibility and convenience.

During growth: the ideal EC is 1 800–2 000 µS.

- **In the first week after transplanting all plants:** reduce to 1 000–1 500 µS.

Why lower EC at the beginning?

- Young seedlings have delicate, undeveloped roots. If the salt concentration is too high, water flows out of the roots instead of in (a process called reverse osmosis).
- **The result:** dehydration and possibly plant collapse.

Other useful parameters:

- **pH:** ideally between 5.5 and 6.5, but organic hydroponic systems can withstand up to 8.5.
- **Solution temperature:** up to 38 °C in organic outdoor hydroponics.
- **Oxygenation:** roots need air too! Check that pumps or air stones are working well, otherwise root rot can occur.

Managing fertilizers

Fertilizers are added to the plants to promote a strong harvest. Fertilizers can be added manually by hand or automatically, with dosing pumps controlled remotely (via the app).The fertilizers used on the system at St. Kizito High School are organic-based and contain:

Macronutrients:

- Nitrogen (N) → for strong leaves and stems
- Phosphorus (P) → for healthy roots and flowers
- Potassium (K) → for quality and overall resistance

Micronutrients: iron, copper, zinc, manganese, calcium, boron

The right balance depends on the growth stage:

- In early growth → more nitrogen
- During flowering/fruiting → more Phosphorus and potassium

Harvesting and replacing plants

Every plant has its own rhythm. Here are a few examples:

- **Lettuce:** ready in about one month. You can harvest it completely and replace it or cut it and let it regrow up to 2–3 times.
- **Swiss chard**: can be harvested leaf by leaf every month and it keeps producing for a long time.
- **Herbs (basil, mint, parsley, etc.):** benefit from regular trimming, which stimulates fresh growth.

Replacement options:

- Sow seeds in growing media (rockwool, perlite, coco coir)
- Use net pots with a little soil and cotton gauze, however, it is usually better to germinate separately in a nursery before transplanting
- Buy ready seedlings and transfer them directly into the system

Students learning how to care for plants

© Helen Lugada

Nursery management

Seedlings are kept in a nursery from the beginning of the germination phase until they are ready to be transplanted to the main hydroponic system.

- **Germination phase:** provide bright light but avoid direct sunlight. Keep humidity steady—the substrate should stay moist, not waterlogged.
- **Transplanting:** once seedlings have at least 4–6 true leaves, they are ready to move into the hydroponic setup.
- **Seed production in the hydroponic system:** let some plants complete their life cycle and flower. Small seeds can be collected using cotton bags placed around the flower heads before they fall naturally.

Fun fact: Seeds collected from plants grown hydroponically are often better adapted to grow in water, which means they usually perform better in the next cycle.

Long-term maintenance

While quick daily or weekly check-ins keep everything running, a hydroponic system also needs deeper maintenance on a regular schedule. Think of it like giving your setup a "service check" every three months to prevent hidden issues from building up.

Cleaning the biofilter

The biofilter helps keep the water clean and balanced, but over time it collects residues that need to be flushed out. The biofilter should be cleaned approximately every three months.

To clean the biofilter:

- Use the knob at the top of the filter to reverse water flow and push out the trapped dirt.
- For a deeper clean, you can disassemble the filter, rinse the internal components and then reassemble it.
- Once done, make sure the water flow direction is set back to normal.

Checking the pumps

Pumps are the heart of the system. If they stop working properly, plants will quickly suffer. Inspect pumps regularly to ensure a steady flow of water. If the small filter on top looks dirty:

- Switch off the pump
- Open the upper compartment carefully (watch out for small bolts)
- Remove and rinse the filter
- Put everything back together and restart the pump

General system cleaning

As plants grow, they shed roots and leaves. These can accumulate in channels, towers or buckets. Remove any large root pieces or dead leaves during cleaning sessions. This prevents clogs, keeps the water flowing freely and reduces the risk of pests or fungi.

Flushing the lines

Even if the water looks clear, small residues can accumulate inside the pipes. Checking and flushing them regularly avoids blockages and keeps the nutrient mix fresh. To do this:

Open the drain taps at the end of each installation:

- 2 taps per tower
- 1 per Dutch bucket line
- 2 per NFT channel

Let the water run out into a bucket for around four seconds, then close the taps again.

A teacher shows students how to monitor water pH and nutrient levels

© Helen Lugada

Students harvesting their produce for the school kitchen

© Bravado Spa

3

Nutrition in hydroponics and organic hydroponics

Hydroponics is not just about faster growth or higher yields. Research highlights its potential to influence the nutritional quality of crops, from vitamin and mineral levels to antioxidants and food safety. Organic hydroponics, sometimes referred to as *bioponics*, adds another dimension, showing how controlled, pesticide-free systems can deliver produce with unique nutritional benefits.

In this chapter we will explore how hydroponic systems affect plant nutrition, what the evidence says when comparing them to soil cultivation and what changes when organic principles are applied.

How plants receive nutrients in hydroponics

In soil, plants depend on interactions with minerals, organic matter and microbes. Hydroponics simplifies this by providing nutrients directly in solution, in precise concentrations.

This nutrient solution contains:

- **Macronutrients:** nitrogen (N), phosphorus (P), potassium (K)
- **Secondary nutrients:** calcium (Ca), magnesium (Mg), sulfur (S)
- **Micronutrients:** iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo)

Nutritional benefits of hydroponic produce

Research has shown that hydroponically grown vegetables can match or even surpass soil-grown counterparts in terms of nutritional quality.

- **Vitamins:** Lettuce, spinach and herbs often show comparable or higher levels of vitamin C and carotenoids, especially in outdoor hydroponic systems exposed to natural sunlight (Murray *et al.*, 2023).
- **Minerals:** As the solution is tailored, hydroponic crops have consistent mineral profiles (calcium, iron, magnesium), while soil crops are more variable depending on field conditions.
- **Antioxidants:** Exposure to light and mild stress in outdoor systems has been linked to increased polyphenols and flavonoids, important for human health (Gruda *et al.,* 2025).

- **Food safety:** A recent comparative study found significantly lower pesticide residues in hydroponic produce compared to conventional soil-grown vegetables (Wang *et al.*, 2025).

Takeaway: Hydroponics can produce nutrient-rich, clean and safe vegetables, particularly leafy greens and herbs.

Slow Food Uganda
www.slowfooduganda.org

From the garden to the kitchen

© Bravado Spa

The nitrate question

Leafy vegetables tend to accumulate nitrates, which in excessive amounts may pose health concerns.

- Indoor hydroponics: higher nitrate levels if nutrient solution is too concentrated (high EC).
- Organic outdoor hydroponics: tends to show lower nitrate concentrations because nutrients are released more slowly from organic sources. (Gruda *et al.*, 2025).

Practical guideline: Studies suggest maintaining EC between 1 000–1 500 µS in early stages and 1 800–2 000 µS in mature stages to balance growth without excess nitrate uptake.

Organic hydroponics: benefits and challenges

Organic hydroponics is an emerging approach that combines hydroponic efficiency with the principles of organic agriculture. Instead of using synthetic mineral salts as nutrient sources, it uses nutrient sources such as compost teas, fish emulsions or other natural nutrient extracts.

One of the main challenges is nutrient availability. These organic compounds need to be broken down by microbial activity before plants can absorb them, which makes the process more complex than in standard hydroponics.

Organic hydroponics offers important benefits that outweigh the challenges. It reduces reliance on chemical fertilizers, supports environmental sustainability and opens access to markets that value organic certification. In this way, it combines the precision of soilless cultivation with the natural cycling of organic systems, aiming to bridge the gap between high-tech farming and environmentally conscious agriculture.

Benefits

- Lower nitrate accumulation (Park and Williams, 2024)
- Higher antioxidant content due to slower nutrient release and mild nutrient stress
- No pesticide residues, since synthetic chemicals are avoided
- Better consumer perception i.e. "clean" and "pesticide-free" produce.

Challenges

- **Nutrient stability:** organic extracts are less predictable than mineral salts, making EC and pH fluctuate more (Palmitessa *et al.*, 2024)
- **Yields:** often lower than mineral-based hydroponics
- **Certification:** organic labeling is still debated. In the European Union, hydroponics is generally not certified as organic, while in the US certain systems can be.

Key takeaways

Hydroponics is more than just a way to save resources like water, space and time. It also offers benefits for nutrition, food safety and sustainability.

- **Consistent nutrition:** Plants like lettuce, basil or strawberries can grow with uniform levels of vitamins and minerals because nutrients are given directly in solution.
- **Outdoor advantages:** When grown outdoors, hydroponic crops benefit from sunlight and natural conditions, often producing more antioxidants that are good for human health.
- **Organic hydroponics:** Using organic nutrient sources reduces nitrate levels and avoids synthetic pesticides, resulting in cleaner, healthier produce.
- **Food safety:** Hydroponic vegetables generally contain fewer pesticide residues than conventional soil-grown crops.

Overall, hydroponics can:

- Provide reliable, nutrient-rich food for schools, hospitals and communities.
- Supply safe, pesticide-free crops in cities where soil may be polluted.
- Support sustainable farming by saving resources while producing high-quality food.

Vegetables in bounty in the hydroponic garden

© Helen Lugada

Students replacing the net pots in the hydroponic towers

© Saul Kayiza

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